depends have been made by Mr. W. Hugo, senior assistant at Kew Observatory, to whose care and exactitude the research owes a very great deal.   The reduction of the observations is also mainly due to Mr. Hugo.   In several of the special experiments Dr. J. A Harker has given valuable assistance, and various operations have been much facilitated by means of apparatus devised by him.   The main work of checking the reductions and the various calculations requisite in discussing the observations have been done by myself.   I have also taken a considerable number of observations, and in discussing the various sources of trouble I speak from personal experience, supplemented of course by frequent exchange of ideas with Dr. Harker and Mr. Hugo.   At various stages of the investigation I have had valuable advice and assistance from Professor Carey Foster and Mr. W. N. Shaw, to whom the initiation of the research is largely due.

The original cost of the apparatus was partly defrayed by a grant of £100 from the Government Grant Fund, and a contribution of £120 was received last year from the Gunning Fund towards this and other cognate work undertaken by the Kew Observatory Committee.

" A Comparative Crystallographical Study of the Double Selenates of the Series $R_2M(SeO_4)_2,6H_2O$.—Salts in which M is Zinc." By A. E. TUTTON, B.Sc., F.R.S.   Received March 5,—Read March 15, 1900.

(Extended Abstract.)

In two communications to the Chemical Society,* the author presented the results of a detailed study of twenty-two salts of the series of monoclinic double sulphates $R_2M(SO_4)_2,6H_2O$, in which R was represented by potassium, rubidium, and cæsium, and M by magnesium, zinc, iron, manganese, nickel, cobalt, copper, and cadmium. The first of these memoirs dealt with the external morphology of the crystals, and the second with their internal physical properties.

The present investigation refers to the less-known analogous double selenates, in which R is again represented by the alkali metals potassium (atomic weight 39), rubidium (atomic weight 85·2), and cæsium (atomic weight 132·7).   The work on the group containing zinc has been completed, and the results are now communicated.   Topsöe and Christiansen† included in their well-known investigation the potassium salt of the group.

The rubidium and cæsium salts have never been investigated, and the author has been unable to find any evidence of their preparation.

The section-plates and prisms employed in the optical work were prepared by means of the author's cutting and grinding goniometer, in the manner already described in previous memoirs. The new special adjusting apparatus described to the Royal Society in the memoir in the ' Phil. Trans.,' A, for 1899, p. 461, has proved of the greatest service in the preparation of the prisms. All the prisms were obtained with its aid by one adjustment, instead of two (one for each of the two required surfaces). A very useful addition to it has been made in the shape of a pair of special grip-holders, besides those referred to on page 460 of the memoir just quoted. One of these new holders is represented in fig. 1. The upper portion, the stem by which it is attached to the lower end of the crystal-adjusting apparatus, carries two vertical grooves instead of only one, so that the plane within the crystal which is desired to bisect the angle (60°) of the prism can always be preliminarily roughly arranged at right angles to the 120° adjusting segment, whatever be the situation of the most convenient direction of gripping. The stem passes down into a thicker solid cylindrical portion, surrounded by a closely fitting hollow cylinder capable of movement for somewhat over 90°, and fixation at any position, by means of slits at different levels and two clamping screws passing through them into the solid cylinder. This enables the necessary final azimuth adjustment of the crystal to be effected, so that the particular bisecting plane referred to can be set exactly to the required orientation, with the aid of the goniometer and its graduated adjusting movements. The gripper is attached rigidly to the underside of the movable cylinder. Its two prongs are arranged to be drawn together by means of a screw manipulated with a milled-headed key, and the gripping lower part is thickened and padded with chamois leather. The use of one of these holders, which only differ in the size of the gripper so as to accommodate different sized crystals, avoids the use of warm wax, which may cause efflorence, or cracking, of the crystal.

FIG. 1.

Every prism employed was prepared by the aid of this instrument so that the two surfaces were symmetrical to one of the three principal planes of the optical ellipsoid (indicatrix), and its edge parallel to one of the two rectangular axes of the indicatrix lying in this plane. It therefore yielded two of the three refractive indices directly, namely, those corresponding to vibrations parallel to the two rectangular axes of the optical indicatrix lying in the bisecting plane.

The salts were prepared in the following manner:—A quantity of
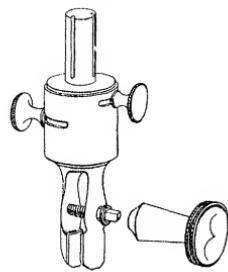
the alkaline selenate crystals, prepared as described in the author's memoir on the normal alkaline selenates,* adequate to yield after addition to the calculated amount of the M-selenate sufficient of the double salt for all the purposes of the investigation, was dissolved in the minimum of distilled water. An equal molecular proportion of pure zinc sulphate crystals was also weighed out, dissolved in distilled water, and precipitated by a solution of sodium carbonate. The precipitate of basic zinc carbonate was isolated by decantation and prolonged washing with hot water, and subsequently dissolved in a solution of pure selenic acid, whose strength had previously been accurately determined by titration with a solution of pure anhydrous sodium carbonate of known strength. Sufficient of the acid was run in upon the zinc carbonate to provide for one drop of excess, as this prevents the possibility of a basic salt forming after addition of the selenate of the R-metal. The solutions of the two selenates were mixed and allowed to crystallise spontaneously, taking all the precautions to avoid disturbance enumerated in the previous memoirs.

The spherical projection given on p. 343 of the double sulphate memoir applies equally to the double selenates.

POTASSIUM ZINC SELENATE, $K_2Zn(SeO_4)_2,6H_2O$.

A determination of the zinc in a quantity of the crystals employed gave the following result:—0·9152 gramme yielded 0·1396 gramme ZnO, corresponding to 12·24 per cent. of zinc. Calculated per cent. Zn = 12·11.

Goniometry.

Ten excellent crystals were employed, derived from several different crops.

Habit: Short prismatic to tabular.

Axial angle— $\beta = 75° 48'$.

Ratio of axes—

$$a : b : c = 0·7458 : 1 : 0·5073.$$

Forms observed—

$a = \{100\}\infty P\infty$; $b = \{010\}\infty P\infty$; $c = \{001\}oP$; $p = \{110\}\infty P$;

$p' = \{120\}\infty P2$; $q = \{011\}P\infty$; $o' = \{\bar{1}11\}+P$; $r' = \{\bar{2}01\}+2P\infty$.

The results of the angular measurements are given in the accompanying table.

The habits observed resembled those exhibited in the following figures given in the double-sulphate memoir :—Fig. 7 without b faces, fig. 8 without the smaller faces, fig. 20, fig. 21, fig. 24, and fig. 25.

* 'Journ. Chem. Soc.,' 1897, p. 846.

Morphological Angles of Potassium Zinc Selenate.

Angle measured.	No. of measurements.	Limits.		Mean observed.	Calculated.	Diff.
		° ′ ° ′		° ′	° ′	′
ac = 100 : 001 = β	5	75 43—	75 55	75 45	75 48	3
as = 100 : 101	—	—		—	46 19	—
sc = 101 : 001	—	—		—	29 29	—
cr' = 001 : $\bar{2}$01	16	63 4—	63 25	63 15	63 12	3
cs' = 001 : $\bar{1}$01	—	—		—	38 22	—
$s'r$ = $\bar{1}$01 : $\bar{2}$01	—	—		—	24 50	—
$r'a$ = $\bar{2}$01 : $\bar{1}$00	5	40 50—	41 0	40 56	41 0	4
$r'c'$ = $\bar{2}$01 : 00$\bar{1}$	16	116 35—	116 56	116 45	116 48	3
ap = 100 : 110	8	35 33—	36 8	35 52	*	—
pp' = 110 : 120	2	19 1—	19 45	19 23	19 28	5
$p'b$ = 120 : 010	1	—		34 39	34 40	1
pb = 110 : 010	10	53 51—	54 24	54 7	54 8	1
pp = 110 : 1$\bar{1}$0	20	71 34—	71 54	71 43	71 44	1
pp = 110 : $\bar{1}$10	20	108 6—	108 32	108 16	108 16	0
cq = 001 : 011	36	26 0—	26 23	26 8	*	—
qb = 011 : 010	12	63 35—	64 8	63 52	63 52	0
qq = 011 : 01$\bar{1}$	13	127 38—	127 53	127 44	127 44	0
ao = 100 : 111	—	—		—	49 35	—
oq = 111 : 011	—	—		—	27 42	—
aq = 100 : 011	—	—		—	77 17	—
qo' = 011 : $\bar{1}$11	—	—		—	34 31	—
$o'a$ = $\bar{1}$11 : $\bar{1}$00	—	—		—	68 12	—
co = 001 : 111	—	—		—	35 11	—
op = 111 : 110	—	—		—	43 21	—
cp = 001 : 110	42	78 22—	78 41	78 32	*	—
po' = 110 : 11$\bar{1}$	3	56 42—	56 53	56 48	56 50	2
$o'c$ = 11$\bar{1}$: 00$\bar{1}$	3	44 37—	44 42	44 39	44 38	1
pc = 110 : 00$\bar{1}$	42	101 21—	101 38	101 29	101 28	1
bo = 010 : 111	—	—		—	69 51	—
os = 111 : 101	—	—		—	20 9	—
bo' = 010 : $\bar{1}$11	—	—		—	65 10	—
$o's'$ = $\bar{1}$11 : $\bar{1}$01	—	—		—	24 50	—
sq = 101 : 011	—	—		—	38 36	—
qp = 011 : $\bar{1}$10	35	85 14—	85 48	85 29	85 26	3
ps = $\bar{1}$10 : $\bar{1}$0$\bar{1}$	—	—		—	55 58	—
pq = $\bar{1}$10 : 0$\bar{1}\bar{1}$	35	94 14—	94 49	94 31	94 34	3
$s'q$ = $\bar{1}$01 : 011	—	—		—	45 15	—
qp = 011 : 110	34	63 59—	64 24	64 9	64 7	2
ps' = 110 : 10$\bar{1}$	—	—		—	70 38	—
pq = 110 : 0$\bar{1}\bar{1}$	34	115 27—	116 0	115 51	115 53	2
$r'o'$ = $\bar{2}$01 : $\bar{1}$11	3	34 27—	34 46	34 33	34 33	0
$o'p$ = $\bar{1}$11 : 110	3	93 10—	93 26	93 17	93 10	7
pr' = 110 : 20$\bar{1}$	33	52 1—	52 28	52 17	52 17	0
$r'p$ = $\bar{2}$01 : 110	31	127 29—	127 56	127 43	127 43	0

Total number of measurements, 462.

The a and b faces were usually both well defined; the hemi-pyramid o' was occasionally well developed, but more usually small, while small p' faces were only observed on two crystals. The general type exhibited p,c,r' and q as the main faces, c always large, and r' occasionally large but generally rather smaller than the q faces.

Topsöe and Christiansen (*loc. cit.*, p. 77) give for the ratio of the axes and the axial angle, $a : b : c = 0{\cdot}7441 : 1 : 0{\cdot}5075$, and $\beta = 75° \; 46'$. The measurements were made by Topsöe in the year 1870.

There is an excellent cleavage parallel to the faces of $r'\{\bar{2}01\}$, as stated by Topsöe and Christiansen.

Volume.

Relative Density.—The following four independent determinations were made :—

Weight of salt employed.	Sp. gr. at 20°/4°.
5·5358	2·5535
6·1058	2·5544
5·1597	2·5524
5·0657	2·5546
Mean............	2·5537

Molecular Volume.—$\dfrac{M}{d} = \dfrac{536{\cdot}6}{2{\cdot}5537} = 210{\cdot}13.$

Distance Ratios.—Combination of the axial ratios and axial angle previously given, with the molecular volume, affords the following distance ratios :—

$$\chi : \psi : \omega = 6{\cdot}1941 : 8{\cdot}3054 : 4{\cdot}2133.$$

Optics.

Orientation of Axes of Optical Ellipsoid.—The plane of the optic axes (optic binormals) is the plane of symmetry. The sign of the double refraction is positive.

Two section-plates ground parallel to the symmetry plane afforded the following extinction angles, relative to the normal to the basal plane :—

Section 1..................	5°	30'
,, 2..................	4	36
Mean.........	5°	3'

The direction is behind the normal, nearer to the vertical axis.

This axis of the optical ellipsoid (indicatrix) is the second median

line.   The first median line is consequently situated in the obtuse angle of the morphological axes *ac*, and is inclined 5° 3′ to the axis *a*. The second median line lies also in the obtuse angle *ac*, and is inclined 9° 9′ to the vertical axis *c*.

Refractive Indices.—The results of the determinations with six prisms, ground on six different crystals, are given in the accompanying table. The values obtained by Topsöe and Christiansen are appended in the last column.   The β values, which were alone determined directly by them, are observed to agree well with the authors' values.

The intermediate refractive index of potassium zinc selenate, corrected to a vacuum, is accurately expressed as far as the neighbourhood of F, for any wave-length λ, by the following formula:—

$$\beta = 1{\cdot}5010 + \frac{694\ 100}{\lambda^2} - \frac{3\ 005\ 700\ 000\ 000}{\lambda^4} + \ \dots$$

As the dispersion increases with the numerical value of the index, the α and γ indices are not precisely reproduced by diminishing and increasing the constant $1{\cdot}5010$ by fixed amounts; but they are on the average less and greater respectively than the β values by $0{\cdot}0060$ and $0{\cdot}0154$.

Alteration of Refraction by Rise of Temperature.—Determinations carried out at 60° indicated that the indices are diminished by about $0{\cdot}0020$ for 45° rise of temperature.

Axes of the Optical Ellipsoid.—The calculated values of the axial ratios of the two optical ellipsoids are as follows:—

Axes of optical indicatrix:

$$\alpha : \beta : \gamma = 0{\cdot}9960 : 1 : 1{\cdot}0101.$$

Axes of optical velocity ellipsoid:

$$\mathfrak{a} : \mathfrak{b} : \mathfrak{c} = 1{\cdot}0040 : 1 : 0{\cdot}9900.$$

Refractive Indices of Potassium Zinc Selenate.

	Light.	Prism 1.	Prism 2.	Prism 3.	Prism 4.	Prism 5.	Prism 6.	Mean.	Values of Topsöe and Christiansen.
α. Vibrations parallel 2nd median line	Li	1·5094	1·5092	1·5082	—	1·5080	—	1·5087	—
	C	1·5099	1·5099	1·5086	—	1·5055	—	1·5092	—
	Na	1·5128	1·5125	1·5115	—	1·5114	—	1·5121	1·5115
	Tl	1·5158	1·5155	1·5146	—	1·5144	—	1·5151	—
	F	1·5195	1·5194	1·5184	—	1·5181	—	1·5189	—
	G	1·5250	1·5249	1·5238	—	1·5237	—	1·5244	—
β. Vibrations parallel symmetry axis *b*	Li	1·5157	—	1·5145	1·5143	—	1·5140	1·5146	—
	C	1·5162	—	1·5151	1·5148	—	1·5145	1·5151	1·5148
	Na	1·5193	—	1·5179	1·5177	—	1·5176	1·5181	1·5177
	Tl	1·5223	—	1·5210	1·5208	—	1·5205	1·5212	—
	F	1·5263	—	1·5251	1·5248	—	1·5247	1·5252	1·5252
	G	1·5317	—	1·5305	1·5305	—	1·5302	1·5307	1·5308
γ. Vibrations parallel 1st median line	Li	—	1·5305	—	1·5294	1·5295	1·5295	1·5297	—
	C	—	1·5309	—	1·5300	1·5300	1·5300	1·5302	—
	Na	—	1·5343	—	1·5333	1·5332	1·5333	1·5335	1·5327
	Tl	—	1·5377	—	1·5365	1·5367	1·5365	1·5369	—
	F	—	1·5417	—	1·5407	1·5407	1·5408	1·5410	—
	G	—	1·5478	—	1·5469	1·5469	1·5469	1·5471	—

Molecular Optical Constants.—Following are the values of these constants :—

Axis of optical indicatrix.		α.	β.	γ.
Specific refraction, $\dfrac{n^2-1}{(n^2+2)d} = n$ .... $\begin{cases} C \\ G \end{cases}$		0·1170 0·1199	0·1181 0·1211	0·1210 0·1242
Molecular refraction, $\dfrac{n^2-1}{n^2+2} \cdot \dfrac{M}{d} = m$ .. $\begin{cases} C \\ G \end{cases}$		62·76 64·33	63·37 64·98	64·93 66·65
Specific dispersion, $n_G - n_C$		0·0029	0·0030	0·0032
Molecular dispersion, $m_G - m_C$		1·57	1·61	1·72
Molecular refraction, $\dfrac{n-1}{d} M$ C		107·00	108·24	111·41

Optic Axial Angle.—Three excellent pairs of section-plates were ground, perpendicular to the first and second median lines respectively.

Determination of Apparent Angle in Air of Potassium Zinc Selenate.

Light.	Section 1.		Section 2.		Section 3.		Mean 2E.	
Li	112°	12′	111°	34′	111°	56′	111°	54′
C	112	14	111	40	112	0	111	58
Na	112	24	112	8	112	19	112	17
Tl	112	40	112	35	112	41	112	39
F	112	58	113	1	113	10	113	3

Topsöe and Christiansen give for the angle in air 111° 50′, and for the true angle 66° 8′, both being measured in sodium light.

The dispersion is observed to be extremely small, and the most accurate measurement is required to determine it, employing sections which afford very small rings and sharp brushes.   A valuable confirmation of the nature of the dispersion is afforded by immersion in cedar oil, whose refraction is almost exactly the same as that of the crystals. A section perpendicular to the first median line shows, in cedar oil, brushes separated at their true angle and fringed with colour according to the following scheme :—

red | blue   1st M.L.   no colour | no colour.

The obtuse morphological axial angle ac is assumed to be to the left. The optic axial angle is therefore greater for blue than for red, and measurements in Li and F light gave an angle larger in the latter case by about 5′, thus confirming the accuracy of the values given in the table.

Determination of True Optic Axial Angle of Potassium Zinc Selenate.

Light.	No. of section perpendicular 1st median line.	Observed values of 2Ha.		No. of section perpendicular 2nd median line.	Observed values of 2Ho.		Calculated values of 2Va.		Mean value of 2Va.	
		°	′		°	′	°	′	°	′
Li	1	60	7	1a	100	12	66	16		
	2	59	54	2a	100	8	66	8	66	12
	3	60	3	3a	100	14	66	13		
C	1	60	5	1a	100	8	66	16		
	2	59	52	2a	100	4	66	8	66	13
	3	60	0	3a	100	6	66	14		
Na	1	59	54	1a	99	42	66	18		
	2	59	43	2a	99	39	66	10	66	15
	3	59	49	3a	99	39	66	16		
Tl	1	59	39	1a	99	5	66	20		
	2	59	31	2a	99	3	66	14	66	17
	3	59	36	3a	99	5	66	18		
F	1	59	17	1a	93	17	66	22		
	2	59	11	2a	98	15	66	18	66	20
	3	59	19	3a	98	25	66	20		

Dispersion of the Median Lines.—In cedar oil no appreciable movement of the right brush, that corresponding to the optic axis situated in the acute morphological angle ac, was detected on altering the wave-length of the light, the total movement occurring at the left brush. Hence the first median line lies nearer to the morphological axis a for red than for blue. The amount does not exceed 5′.

Effect of Rise of Temperature on the Optic Axial Angle.—Measurements at 65° indicated that 2E increases $2\frac{1}{2}$° for 50° rise of temperature.

RUBIDIUM ZINC SELENATE, $Rb_2Zn(SeO_4)_2,6H_2O$.

An estimation of zinc in a specimen of the crystals employed afforded the following guarantee of purity : 1·1130 grammes yielded 0·1426 gramme ZnO, which corresponds to 10·28 per cent. of zinc. Calculated Zn = 10·33.

Goniometry.

Ten suitable small crystals were employed, belonging to four different crops.

Habit : thick tabular, sometimes prismatic.

Morphological Angles of Rubidium Zinc Selenate.

Angle measured.	No. of measurements.	Limits.		Mean observed.	Calculated.	Diff.
		° ′ ° ′		° ′	° ′	′
ac = 100 : 001 = β	—	—		—	74 44	—
as = 100 : 101	—	—		—	45 47	—
sc = 101 : 001	—	—		—	28 57	—
cr' = 001 : $\bar{2}$01	9	63 45— 64 2		63 53	63 42	11
cs' = 001 : $\bar{1}$01	—	—		—	38 24	—
$s'r'$ = $\bar{1}$01 : $\bar{2}$01	—	—		—	25 18	—
$r'a$ = $\bar{2}$01 : $\bar{1}$00	—	—		—	41 34	—
$r'c$ = $\bar{2}$01 : 00$\bar{1}$	11	115 57 —116 15		116 4	116 18	14
ap = 100 : 110	—	—		—	35 38	—
pp' = 110 : 120	—	—		—	19 28	—
$p'b$ = 120 : 010	—	—		—	34 54	—
pb = 110 : 010	2	54 15— 54 27		54 21	54 22	\1
pp = 110 : 1$\bar{1}$0	20	71 6— 71 39		71 15	*	
pp = 110 : $\bar{1}$10	20	108 21—109 1		108 45	108 45	0
cq = 001 : 011	21	25 35— 26 7		25 50	*	—
qb = 011 : 010	2	64 10— 64 16		64 13	64 10	3
qq = 011 : 01$\bar{1}$	17	128 3—128 26		128 25	128 20	5
ao = 100 : 111	—	—		—	48 59	—
oq = 111 : 011	—	—		—	27 19	—
aq = 100 : 011	—	—		—	76 18	—
qo' = 011 : $\bar{1}$11	—	—		—	34 37	—
$o'a$ = $\bar{1}$11 : $\bar{1}$00	—	—		—	69 5	—
co = 001 : 111	—	—		—	34 34	—
op = 111 : 110	—	—		—	43 5	—
cp = 001 : 110	35	77 28— 77 57		77 39	*	—
po' = 110 : 11$\bar{1}$	3	57 33— 57 37		57 35	57 43	8
$o'c$ = 11$\bar{1}$: 00$\bar{1}$	3	44 40— 44 47		44 45	44 38	7
pc = 110 : 00$\bar{1}$	34	102 10—102 36		102 21	102 21	0
bo = 010 : 111	—	—		—	70 13	—
os = 111 : 101	—	—		—	19 47	—
bo' = 010 : $\bar{1}$11	3	65 9— 65 17		65 14	65 14	0
$o's'$ = $\bar{1}$11 : $\bar{1}$01	—	—		—	24 46	—
$o'o'$ = $\bar{1}$11 : $\bar{1}\bar{1}$1	1	—		49 34	49 32	2
sq = 101 : 011	—	—		—	38 2	—
qn' = 011 : $\bar{1}$21	1	—		35 46	35 33	13
$n'p$ = $\bar{1}$21 : $\bar{1}$10	1	—		50 44	50 57	13
qp = 011 : $\bar{1}$10	26	86 14— 86 49		86 37	86 30	7
ps = $\bar{1}$10 : $\bar{1}$0$\bar{1}$	—	—		—	55 28	—
pq = $\bar{1}$10 : 0$\bar{1}\bar{1}$	26	93 6— 93 36		93 23	93 30	7
$s'q$ = $\bar{1}$01 : 011	—	—		—	45 8	—
qp = 011 : 110	28	63 26— 63 55		63 38	63 30	8
ps' = 110 : 10$\bar{1}$	—	—		—	71 22	—
pq = 110 : 0$\bar{1}\bar{1}$	28	116 6—116 38		116 23	116 30	7
$r'o'$ = $\bar{2}$01 : $\bar{1}$11	3	34 51— 34 53		34 52	34 49	3
$o'p$ = $\bar{1}$11 : 110	3	92 44— 92 47		92 45	92 39	6
pr' = 110 : 20$\bar{1}$	29	52 12— 52 32		52 21	52 32	11
$r'p$ = $\bar{2}$01 : 110	28	127 23—127 50		127 39	127 28	11

Total number of measurements, 354.

Axial angle : $\beta = 74° 44'$.

Ratio of axes : $a : b : c = 0{\cdot}7431 : 1 : 0{\cdot}5019$.

Forms observed : $a = \{100\}\infty P\infty$; $b = \{010\}\infty R\infty$; $c = \{001\}oP$;
$\qquad\qquad p = \{110\}\infty P$; $q = \{011\}R\infty$; $o' = \{\bar{1}11\}+P$;
$\qquad\qquad r' = \{\bar{2}01\}+2P\infty$; $n' = \{\bar{1}21\}+2P2$.

The results of the measurements are tabulated in the accompanying table.

The types observed resembled those of rubidium zinc sulphate, especially that shown in fig. 7 (p. 359) of the double-sulphate memoir, but without the b faces as a rule. Only a trace of the orthopinacoid a was discovered ; the clinopinacoid b was invariably small when present, and the hemi-pyramid n' was only present on one of the crystals measured. The o' faces were fairly well developed, and afforded good images of the signal. Frequently the only faces present were c, p, r', and q. The c faces varied in relative importance from the breadth usually exhibited in the potassium salts to the narrow strip characteristic of the cæsium salt.

There is an excellent cleavage parallel to the faces of the orthodome $r'\{\bar{2}01\}$.

Volume.

Relative Density.—The following four determinations were made with independent quantities of the finely-powdered crystals :—

Weight of salt employed.	Sp. gr. at $20°/4°$.
7·8234	2·8596
6·0506	2·8611
7·8824	2·8601
6·7490	2·8608
Mean	2·8604

Molecular Volume.— $\dfrac{M}{d} = \dfrac{629{\cdot}0}{2{\cdot}8604} = 219{\cdot}90$.

Distance Ratios.—On combining the axial angle and the ratio of the axes already given, with the molecular volume, the following ratios are obtained :—

$$\chi : \psi : \omega = 6{\cdot}3062 : 8{\cdot}4863 : 4{\cdot}2593.$$

Optics.

Orientation of Axes of Optical Ellipsoid.—The optic axes (optic binormals) lie in the plane of symmetry. The sign of the double refraction is positive.

The following extinction angles were exhibited by two section-plates

ground parallel to the symmetry plane, with reference to the normal to the basal plane :—

Section 1	2°	0′
Section 2	2	7
Mean......	2	3

The direction is behind the normal, towards the vertical morphological axis. This axis of the optical indicatrix is again the second median line.

The first median line thus lies in the obtuse morphological axial angle *ac*, and is inclined 2° 3′ to the axis *a*. The second median line lies also in the obtuse angle *ac*, and is inclined 13° 13′ to the vertical axis *c*.

Refractive Indices.—Six prisms, ground on six different crystals belonging to various crops, were employed in the determinations. The results are given in the accompanying table :—

Refractive Indices of Rubidium Zinc Selenate.

Index.	Light.	Prism 1.	Prism 2.	Prism 3.	Prism 4.	Prism 5.	Prism 6.	Mean.
α Vibr. par. 2 M.L.	Li	1·5123	—	—	1·5132	1·5135	1·5126	1·5129
	C	1·5128	—	—	1·5136	1·5141	1·5132	1·5134
	Na	1·5165	—	—	1·5167	1·5167	1·5159	1·5162
	Tl	1·5188	—	—	1·5197	1·5201	1·5190	1·5194
	F	1·5228	—	—	1·5234	1·5240	1·5229	1·5233
	G	1·5284	—	—	1·5288	1·5295	1·5284	1·5288
β Vibr. par. symn. axis.	Li	1·5187	1·5175	1·5198	—	1·5190	—	1·5188
	C	1·5192	1·5181	1·5201	—	1·5197	—	1·5193
	Na	1·5220	1·5210	1·5230	—	1·5227	—	1·5222
	Tl	1·5251	1·5241	1·5261	—	1·5258	—	1·5253
	F	1·5291	1·5280	1·5302	—	1·5297	—	1·5293
	G	1·5350	1·5338	1·5360	—	1·5354	—	1·5351
γ Vibr. par. 1 M.L.	Li	—	1·5286	1·5299	1·5298	—	1·5294	1·5294
	C	—	1·5290	1·5304	1·5303	—	1·5298	1·5299
	Na	—	1·5323	1·5336	1·5335	—	1·5330	1·5331
	Tl	—	1·5355	1·5369	1·5370	—	1·5367	1·5365
	F	—	1·5396	1·5408	1·5411	—	1·5405	1·5405
	G	—	1·5457	1·5469	1·5472	—	1·5466	1·5466

The intermediate refractive index of rubidium zinc selenate, corrected to a vacuum, is expressed as far as F, for any wave-length λ, by the formula :—

$$\beta = 1 \cdot 5067 + \frac{592\ 314}{\lambda^2} - \frac{1\ 397\ 600\ 000\ 000}{\lambda^4} + \ldots .$$

The α indices are very closely reproduced by the formula if the con-

stant 1·5067 is diminished by 0·0060; owing to appreciably increased dispersion in the γ direction, the γ indices are not so accurately reproduced, but are approximately given if the constant is increased by 0·0109.

Alteration of Refraction by Rise of Temperature.—Determinations at 60° showed that the indices are reduced by 0·0018 by 45° rise of temperature (15—60°).

Axes of the Optical Ellipsoid.—Following are the values of the axial ratios of the two optical ellipsoids—

Axes of optical indicatrix:

$$\alpha : \beta : \gamma = 0·9961 : 1 : 1·0072.$$

Axes of optical velocity ellipsoid:

$$\mathfrak{a} : \mathfrak{b} : \mathfrak{c} = 1·0039 : 1 : 0·9929.$$

Molecular Optical Constants.—The calculated values of these constants are as follows:—

Axis of optical indicatrix.		α.	β.	γ.
Specific refraction, $\dfrac{n^2-1}{(n^2+2)d} = \mathfrak{n}$	$\begin{cases} C \\ G \end{cases}$	0·1051 0·1078	0·1062 0·1089	0·1080 0·1108
Molecular refraction, $\dfrac{n^2-1}{n^2+2} \cdot \dfrac{M}{d} = \mathfrak{m}$	$\begin{cases} C \\ G \end{cases}$	66·13 67·80	66·77 68·47	67·92 69·70
Specific dispersion, $\mathfrak{n}_G - \mathfrak{n}_C$		0·0027	0·0027	0·0028
Molecular dispersion, $\mathfrak{m}_G - \mathfrak{m}_C$		1·67	1·70	1·78
Molecular refraction, $\dfrac{n-1}{d}M$ C		112·90	114·20	116·53

Optic Axial Angle.—The following measurements were obtained with the aid of three pairs of section-plates, ground perpendicular to the first and second median lines, according to the indications of their orientation afforded by the extinction angles:—

Apparent Angle in Air of Rubidium Zinc Selenate.

Light.	Section 1.		Section 2.		Section 3.		Mean 2E.	
	°	′	°	′	°	′	°	′
Li	135	2	139	0	138	22	137	28
C	135	7	139	6	138	28	137	34
Na	135	23	139	32	139	5	138	0
Tl	135	43	139	55	139	40	138	26
F	136	15	140	25	140	19	139	0

Determination of True Optic Axial Angle of Rubidium Zinc Selenate.

Light.	No. of section perpendicular 1st median line.	Observed values of 2Hα.	No. of section perpendicular 2nd median line.	Observed values of 2Ho.	Calculated values of 2Vα.	Mean value of 2Vα.
		° ′		° ′	° ′	° ′
Li	1	67 59	1a	93 39	74 57	
	2	68 21	2a	93 40	75 12	75 16
	3	69 0	3a	93 44	75 38	
C	1	67 55	1a	93 35	74 56	
	2	68 17	2a	93 38	75 10	75 14
	3	68 56	3a	93 .40	75 37	
Na	1	67 31	1a	93 10	74 50	
	2	67 52	2a	93 16	75 2	75 8
	3	68 35	3a	93 20	75 32	
Tl	1	67 8	1a	92 45	74 45	
	2	67 29	2a	92 54	74 56	75 2
	3	68 12	3a	92 56	75 26	
F	1	66 37	1a	92 10	74 38	
	2	67 1	2a	92 26	74 48	74 55
	3	67 45	3a	92 32	75 18	

The dispersion is thus seen to be small, but it is distinctly greater than in the case of the potassium salt. In cedar oil, whose refraction is almost exactly the same as that of this salt, a section perpendicular to the first median line exhibits the brushes fringed with colour as follows :—

blue | red   1st M.L.   red | blue

The optic axial angle is therefore greater for red than for blue, thus confirming the results of the measurements.

Dispersion of the Median Lines.—In the foregoing representation of the coloured brush-fringes as seen in cedar oil, the obtuse angle of the morphological axes *ac* is situated to the left. The hyperbolic brush on this side was more faintly tinted at the edges than the right-hand brush, indicating feebler dispersion of the optic axis to the left. Measurements in cedar oil confirmed this, and showed that the difference between the position of this optic axis for C-light and for F-light was 8—10′, whilst for the right-hand axis it was 20′. Hence the median lines are dispersed so that the first median line lies nearer to the morphological axis *a* by 4—5′ for red light than it does for blue.

Effect of Rise of Temperature on the Optic Axial Angle.—Very little change is introduced in the optic axial angle of this salt by variation

of temperature.   Measurements in succession at 10·5° and 60·5° indicated that 2E increases 30′ for 50° of rise of temperature.

CÆSIUM ZINC SELENATE, $Cs_2Zn(SeO_4)_2,6H_2O$.

The analysis of a specimen of the crystals of this salt afforded the following numbers : 0·7027 gramme gave 0·0790 gramme of ZnO, which corresponds to 9·02 per cent. of zinc.   The calculated percentage is 8·98.

Goniometry.

Eleven of the most suitable small crystals, derived from five different crops, were employed in the goniometrical measurements.

Habit : flattened prismatic.

Axial angle : $\beta = 73° 49′$.

Ratio of axes : $a : b : c = 0·7314 : 1 : 0·4971$.

Forms observed : $b = \{010\}\infty R\infty$; $c = \{001\}oP$; $p = \{110\}\infty P$; $q = \{011\}R\infty$; $m = \{021\}2R\infty$; $o' = \{\bar{1}11\} + P$; $r' = \{\bar{2}01\} + 2P\infty$.

The results of the measurements are presented in the accompanying table of angles.

The habits of the crystals of the various crops are typified by the following figures of the double sulphate memoir (*loc. cit.*) : figs. 9 and 10 in the description of cæsium zinc sulphate, fig. 16 in the description of cæsium ferrous sulphate, fig. 21, but with much larger q faces, and fig. 34 in the description of cæsium cadmium sulphate as far as regards the relation of the c, r' and q faces.   They are characterised by large q faces relatively to the faces of the basal plane, which latter is usually only represented by a mere strip.   The faces of the hemi-pyramid o' are often considerably developed.

The clinopinacoid b is frequently present, but the orthopinacoid a was never observed.   The clinodome m was found developed on one of the crystals measured.

The cleavage parallel to $r'\{\bar{2}01\}$, common to the series, was well developed.

Morphological Angles of Cæsium Zinc Selenate.

Angle measured.	No. of measurements.	Limits.	Mean observed.	Calculated.	Diff.
		° ′ ° ′	° ′	° ′	′
ac = 100 : 001 = β	—		—	73 49	—
as = 100 : 101	—		—	45 3	—
sc = 101 : 001	—		—	28 46	—
cr' = 001 : $\bar{2}$01	22	64 36— 64 53	64 45	64 36	9
cs' = 001 : $\bar{1}$01	—		—	38 52	—
$s'r'$ = $\bar{1}$01 : $\bar{2}$01	—		—	25 44	—
$r'a$ = $\bar{2}$01 : $\bar{1}$00	—		—	41 35	—
$r'c$ = $\bar{2}$01 : 00$\bar{1}$	19	115 7—115 32	115 16	115 24	8
ap = 100 : 110	—		—	35 4	—
pp' = 110 : 120	—		—	19 28	—
$p'b$ = 120 : 010	—		—	35 28	—
pb = 110 : 010	6	54 46— 55 4	54 54	54 56	2
pp = 110 : 1$\bar{1}$0	19	69 55— 70 21	70 7	*	—
pp = 110 : $\bar{1}$10	20	109 25—110 16	109 52	109 53	1
cq = 001 : 011	30	25 22— 25 42	25 31	*	—
$q\,b$ = 011 : 010	4	64 18— 64 43	64 33	64 29	4
qq = 011 : 01$\bar{1}$	14	128 40—129 12	129 0	128 58	2
ao = 100 : 111	—		—	48 12	—
oq = 111 : 011	—		—	27 14	—
aq = 100 : 011	—		—	75 26	—
qo' = 011 : $\bar{1}$11	—		—	35 6	—
$o'a$ = $\bar{1}$11 : $\bar{1}$00	—		—	69 28	—
co = 001 : 111	—		—	34 13	—
op = 111 : 110	—		—	42 36	—
cp = 001 : 110	37	76 34— 76 57	76 49	*	—
po' = 110 : 11$\bar{1}$	16	57 52— 58 34	58 10	58 14	4
$o'c$ = 11$\bar{1}$: 00$\bar{1}$	17	44 35— 45 21	45 0	44 57	3
pc = 110 : 00$\bar{1}$	36	102 59—103 39	103 11	103 11	0
bo = 010 : 111	—		—	70 37	—
os' = 111 : 101	—		—	19 23	—
bo' = 010 : $\bar{1}$11	—		—	65 22	—
$o's'$ = $\bar{1}$11 : $\bar{1}$01	—		—	24 38	—
sq = 101 : 011	—		—	37 43	—
qp = 011 : $\bar{1}$10	36	87 24— 88 3	87 39	87 37	2
ps = $\bar{1}$10 : $\bar{1}$0$\bar{1}$	—		—	54 40	—
pq = $\bar{1}$10 : 0$\bar{1}$$\bar{1}$	36	91 52— 92 36	92 21	92 23	2
$s'q$ = $\bar{1}$01 : 011	—		—	45 21	—
qp = 011 : 110	35	62 50— 63 25	63 7	63 5	2
ps' = 110 : 10$\bar{1}$	—		—	71 34	—
pq = 110 : 0$\bar{1}$$\bar{1}$	35	116 35—117 11	116 53	116 55	2
$r'o'$ = $\bar{2}$01 : $\bar{1}$11	11	34 42— 35 15	34 58	35 2	4
$o'm$ = $\bar{1}$11 : 021	1	—	36 56	36 54	2
mp = 021 : 110	1	—	55 47	55 49	2
$o'p$ = $\bar{1}$11 : 110	12	92 32— 92 58	92 48	92 43	5
pr' = 110 : 20$\bar{1}$	29	52 2— 52 28	52 12	52 15	3
$r'p$ = $\bar{2}$01 : 110	28	127 25—128 2	127 48	127 45	3

Total number of measurements, 464.

Volume.

Relative Density.—Four determinations with independent material afforded the following results :—

Weight of salt employed.	Sp. gr. at 20°/4°.
5·2958	3·1148
5·5387	3·1175
5·1525	3·1126
5·5317	3·1164
Mean	3·1153

Molecular Volume.— $\dfrac{M}{d} = \dfrac{724\cdot0}{3\cdot1153} = 232\cdot40.$

Distance Ratios.—Combination of this molecular volume with the axial angle and axial ratios already given, affords the following distance ratios :—

$$\chi : \psi : \omega = 6\cdot3860 : 8\cdot7311 : 4\cdot3402.$$

Optics.

Orientation of Axes of Optical Ellipsoid.—The plane of the optic axes (bi-normals) is again the plane of symmetry. The sign of the double refraction is also still positive, as for the potassium and rubidium salts.

Stauroscopic observations carried out with two section-plates ground parallel to the symmetry plane gave the following extinction angles with reference to the normal to the basal plane :—

Section 1	6°	7′
Section 2	5	26
Mean	5	46

The direction is in front of the normal, nearer to the inclined morphological axis a. This axis of the optical indicatrix is the second median line. The first median line is accordingly situated in the acute angle of the morphological axes ac, and is inclined 5° 46′ to the axis a. The second median line lies in the obtuse angle ac, and is inclined 21° 57′ to the vertical axis c.

Refractive Indices.—The results of the refractive index determinations with six prisms, ground on crystals from different crops, are presented in the accompanying table.

The intermediate refractive index of cæsium zinc selenate, corrected to a vacuum, is expressed to near F, for any wave-length λ, by the following formula :—

$$\beta = 1\cdot5187 + \frac{704\ 232}{\lambda^2} - \frac{2\ 877\ 600\ 000\ 900}{\lambda^4} + \ \ldots\ .$$

The α indices are reproduced with precisely equal accuracy if the constant 1·5187 is diminished by 0·0036 ; owing to slightly increased dispersion exhibited by the γ indices, these values are reproduced with slightly less accuracy when the constant is increased by the average amount of 0·0050.

Alteration of Refraction by Rise of Temperature.—Measurements of the prism angle and minimum deviation at 60°, indicated that the refractive indices are reduced by 0·0015 for 45° rise of temperature (15° to 60°).

Axes of the Optical Ellipsoid.—These values are as follows :—

Axes of optical indicatrix : $\alpha : \beta : \gamma = 0\cdot9977 : 1 : 1\cdot0033$.
Axes of optical velocity ellipsoid : $\mathfrak{a} : \mathfrak{b} : \mathfrak{c} = 1\cdot0024 : 1 : 0\cdot9968$.

Refractive Indices of Cæsium Zinc Selenate.

Index.	Light.	Prism 1.	Prism 2.	Prism 3.	Prism 4.	Prism 5.	Prism 6.	Mean.
α Vibr. par. 2 M.L.	Li	—	1·5285	1·5287	1·5296	1·5293	—	1·5290
	C	—	1·5290	1·5292	1·5302	1·5298	—	1·5295
	Na	—	1·5321	1·5323	1·5332	1·5327	—	1·5326
	Tl	—	1·5353	1·5356	1·5362	1·5360	----	1·5358
	F	—	1·5395	1·5396	1·5404	1·5402	—	1·5399
	G	—	1·5454	1·5456	1·5464	1·5461	—	1·5459
β Vibr. par. symm. axis.	Li	1·5323	––	1·5326	—	1·5327	1·5328	1·5326
	C	1·5327	—	1·5332	—	1·5332	1·5334	1·5331
	Na	1·5359	—	1·5361	—	1·5364	1·5365	1·5362
	Tl	1·5391	—	1·5396	—	1·5395	1·5395	1·5394
	F	1·5432	—	1·5434	—	1·5437	1·5437	1·5435
	G	1·5491	—	1·5497	—	1·5496	1·5498	1·5495
γ Vibr. par. 1 M.L.	Li	1·5371	1·5371	—	1·5381	—	1·5376	1·5375
	C	1·5377	1·5377	—	1·5385	—	1·5381	1·5380
	Na	1·5409	1·5408	—	1·5418	—	1·5411	1·5412
	Tl	1·5443	1·5444	—	1·5451	—	1·5445	1·5446
	F	1·5484	1·5486	—	1·5493	—	1·5488	1·5488
	G	1·5544	1·5547	—	1·5554	—	1·5549	1·5549

Molecular Optical Constants.—These are as under :—

Axis of optical indicatrix.		α	β	γ
Specific refraction, $\dfrac{n^2-1}{(n^2+2)d} = \mathfrak{n}$	C	0·0991	0·0996	0·1004
	G	0·1016	0·1022	0·1030
Molecular refraction, $\dfrac{n^2-1}{n^2+2} \cdot \dfrac{M}{d} = \mathfrak{m}$ ..	C	71·73	72·14	72·69
	G	73·58	73·98	74·58
Specific dispersion, $\mathfrak{n}_G - \mathfrak{n}_C$		0·0025	0·0026	0·0026
Molecular dispersion, $\mathfrak{m}_G - \mathfrak{m}$		1·85	1·84	1·89
Molecular refraction, $\dfrac{n-1}{d}M$ C		123·06	123·89	125·03

Optic Axial Angle.—The optic axial angle in air 2E is so large as to be only measurable with some difficulty, even in the cases of the largest and most perfectly transparent sections.   Owing to the relatively small double refraction of all the salts of this series, sections require to have a thickness of at least a millimetre in order to afford small rings and sharp brushes.   Hence, if the section is not of considerable, and not always attainable, relative breadth the brushes become obscured.   Two of the sections prepared enabled trustworthy measurements to be obtained, but the others, although excellent for 2H*a*, did not exhibit adequately clear brushes in air.

Apparent Angle in Air of Cæsium Zinc Selenate.

Light.	Section 1.		Section 2.		Mean 2E.	
	°	′	°	′	°	′
Li	162	50	165	20	164	5
C	163	12	165	33	164	22
Na	165	43	166	30	166	6
Tl	168	21	167	23	167	52

No measurements were obtainable beyond the green, the angle becoming too large.

From the results given in the accompanying table for the true angle, it will be observed that the dispersion of the optic axes is considerably greater than in the cases of the potassium and rubidium salts.   To confirm its nature, and determine the dispersion of the median lines, a liquid was sought for whose refraction was the same as that of the crystals, and which was without action on them.   Pure methyl salicylate fulfils these conditions, and the interference figures afforded by sections perpendicular to the first median line were observed, while immersed in a cell of this liquid.   Measurements in C and F light afforded angles almost identical with those calculated from 2H*a* and 2H*o* as measured in monobromonaphthalene, and showing the same amount and order of dispersion.

Four pairs of section plates were employed in the determinations of the true angle.

Determination of True Optic Axial Angle of Cæsium Zinc Selenate.

Light.	No. of section perpendicular 1st median line.	Observed values of 2H*a*.	No. of section perpendicular 2nd median line.	Observed values of 2H*o*.	Calculated values of 2V*a*.	Mean value of 2V*a*.
		° ′		° ′	° ′	° ′
Li	1	76 27	1*a*	87 33	83 37	
	2	76 12	2*a*	87 28	83 30	83 33
	3	76 15	3*a*	87 30	83 31	
	4	76 20	4*a*	87 30	83 34	
C	1	76 23	1*a*	87 32	83 34	
	2	76 6	2*a*	87 27	83 27	83 30
	3	76 9	3*a*	87 29	83 28	
	4	76 14	4*a*	87 28	83 32	
Na	1	75 43	1*a*	87 26	83 12	
	2	75 26	2*a*	87 23	83 4	83 6
	3	75 25	3*a*	87 27	83 1	
	4	75 29	4*a*	87 24	83 5	
Tl	1	75 1	1*a*	87 18	82 50	
	2	74 47	2*a*	87 18	82 41	82 43
	3	74 49	3*a*	87 24	82 39	
	4	74 49	4*a*	87 20	82 41	
F	1	74 17	1*a*	87 9	82 26	
	2	73 53	2*a*	87 11	82 10	82 14
	3	73 55	3*a*	87 21	82 6	
	4	74 0	4*a*	87 14	82 12	

Dispersion of the Median Lines.—When the true angle is observed in methyl salicylate in white light, the brushes are seen to be highly coloured in accordance with the following scheme :—

blue | red   1st M.L.   red | blue.

The angle is thus indubitably the larger for red. If the section is arranged so that the obtuse angle of the morphological axes *ac* is situated to the left, the optic axis to the right is found to be less dispersed between C and Tl light by about 10′ than the left-hand axis. Hence the median lines are dispersed by about 5′ between the same wave-lengths, and so that the first median line lies nearer to the morphological axis *a* for red than for green.

Effect of Rise of Temperature on the Optic Axial Angle.—Repeated measurements of 2E with the best of the sections at 60°, indicated that the angle in air decreases about 3° for 50° rise of temperature.

<center>*Comparison of the Three Salts.*</center>

A concise statement of the conclusions to be drawn from a comparison of the results for the three salts will be found in the Abstract published in the 'Proceedings of the Royal Society,' vol. 66, p. 248.   The following comparative tables and diagrams will enable these conclusions to be clearly appreciated.

Comparison of the Morphological Angles of the Three Zinc Salts.

Angle.	Potassium salt.		Diff.	Rubidium salt.		Diff.	Cæsium salt.	
	°	′	′	°	′	′	°	′
$ac = 100 : 001 = \beta$	75	48	−64	74	44	−55	73	49
$as = 100 : 101$	46	19	−32	45	47	−44	45	3
$sc = 101 : 001$	29	29	—	28	57	—	28	46
$cr' = 001 : \bar{2}01$	63	12(15)	+30	63	42(53)	+54	64	36
$cs' = 001 : \bar{1}01$	38	22	—	38	24	—	38	52
$s'r' = \bar{1}01 : \bar{2}01$	24	50	+28	25	18	+26	25	44
$r'a = \bar{2}01 : \bar{1}00$	41	0	—	41	34	—	41	35
$ap = 100 : 110$	35	52	−14	35	38	−34	35	4
$pp' = 110 : 1\bar{2}0$	19	28	—	19	28	—	19	28
$p'b = 1\bar{2}0 : 010$	34	40	+14	34	54	+34	35	28
$pb = 110 : 010$	54	8	—	54	22	—	54	56
$cq = 001 : 011$	26	8	−18	25	50	−19	25	31
$qb = 011 : 010$	63	52	—	64	10	—	64	29
$ao = 100 : 111$	49	35	−36	48	59	−47	48	12
$oq = 111 : 011$	27	42	—	27	19	—	27	14
$aq = 100 : 011$	77	17	−59	76	18	−52	75	26
$qo' = 011 : \bar{1}11$	34	31	—	34	37	—	35	6
$o'a = \bar{1}11 : \bar{1}00$	68	12	+53	69	5	+23	69	28
$co = 001 : 111$	35	11	−37	34	34	−21	34	13
$op = 111 : 110$	43	21	—	43	5	—	42	36
$cp = 001 : 110$	78	32	−53	77	39	−50	76	49
$po' = 110 : 11\bar{1}$	56	50	—	57	43	—	58	14
$o'c = 11\bar{1} : 00\bar{1}$	44	38	0(+7)	44	38(45)	+19(12)	44	57
$bo = 010 : 111$	69	51	+22	70	13	+24	70	37
$os = 111 : 101$	20	9	—	19	47	—	19	23
$bo' = 010 : \bar{1}11$	65	10	+4	65	14	+8	65	22
$o's' = \bar{1}11 : \bar{1}01$	24	50	—	24	46	—	24	38
$sq = 101 : 011$	38	36	−34	38	2	−19	37	43
$qp = 011 : \bar{1}10$	85	26	+64	86	30	+67	87	37
$ps = \bar{1}10 : \bar{1}0\bar{1}$	55	58	—	55	28	—	54	40
$s'q = \bar{1}01 : 011$	45	15	—	45	8	—	45	21
$qp = 011 : 110$	64	7	−37	63	30	−25	63	5
$ps' = 110 : 10\bar{1}$	70	38	+44	71	22	+12	71	34
$r'o' = \bar{2}01 : \bar{1}11$	34	33	+16	34	49	+13	35	2
$o'p = \bar{1}11 : 110$	93	10	—	92	39	—	92	43
$pr' = 110 : 20\bar{1}$	52	17	+15(4)	52	32(21)	−17(6)	52	15

The minutes figures in brackets in the table are the observed values in those cases where the differences between the observed and calculated values are appreciable.

The angular change is not generally directly proportional to the change in the atomic weight of the alkali metal, the maximum variation from direct proportion among the primary angles being exhibited by the prism zone, where the changes in ap or bp are as 1 to $2\frac{1}{2}$.

Comparison of the Axial Ratios

For potassium zinc selenate, $a : b : c = 0\cdot7458 : 1 : 0\cdot5073$
,, rubidium ,, ,, $a : b : c = 0\cdot7431 : 1 : 0\cdot5019$
,, cæsium ,, ,, $a : b : c = 0\cdot7314 : 1 : 0\cdot4971$.

Comparison of the Relative Densities.

Potassium zinc selenate ...... 2·5537
                                        Diff.   0·3067
Rubidium ,, ,, ... 2·8604
                                        Diff.   0·2549
Cæsium ,, ,, ... 3·1153

The difference between the densities of potassium zinc and rubidium zinc sulphates is 0·343, and between those of the latter salt and cæsium zinc sulphate 0·283.

Comparison of the Molecular Volumes.

Potassium zinc selenate ...... 210·13
                                        Diff.   9·77
Rubidium ,, ,, ... 219·90
                                        Diff.   12·50
Cæsium ,, ,, ... 232·40

The differences for the two replacements in the zinc double sulphates were 9·52 and 12·68.

Comparison of the Distance Ratios.

	χ.	Diff.	ψ.	Diff.	ω.	Diff.
KZn selenate ...	6·1941		8·3054		4·2133	
		1121		1809		460
RbZn ,, ...	6·3062		8·4863		4·2593	
		798		2448		809
CsZn ,, ...	6·3860		8·7311		4·3402	
		1919		4257		1269

These ratios may be simplified by referring them to ψ for KZn selenate as unity, when the values for that salt become identical with the axial ratios.   These ratios are as under :—

	χ.	Diff.	ψ.	Diff.	ω.	Diff.
KZn selenate ...	0·7458		1		0·5073	
		135		218		55
RbZn ,, ...	0·7593		1·0218		0·5128	
		96		295		98
CsZn ,, ...	0·7689		1·0513		0·5226	
		231		513		153

Comparison of the Orientations of the Optical Indicatrix.

Inclinations of Axis a of Indicatrix to Vertical Axis c.

For potassium zinc selenate   9   9

Diff.   4   4

  ,,   rubidium   ,,   ,, ...   13 13

  ,,   8 44

  ,,   cæsium   ,,   ,, ...   21 57

The rotation of the ellipsoid is clearly illustrated by fig. 2.

Comparative Table of Refractive Indices.

Index.	Light.	KZn selenate.	RbZn selenate.	CsZn selenate.
α Vibr. par. 2 M.L.	Li	1·5087	1·5129	1·5290
	C	1·5092	1·5134	1·5295
	Na	1·5121	1·5162	1·5326
	Tl	1·5151	1·5194	1·5358
	F	1·5189	1·5233	1·5399
	G	1·5244	1·5288	1·5459
β Vibr. par. symm. axis.	Li	1·5146	1·5188	1·5326
	C	1·5151	1·5193	1·5331
	Na	1·5181	1·5222	1·5362
	Tl	1·5212	1·5253	1·5394
	F	1·5252	1·5293	1·5435
	G	1·5307	1·5351	1·5495
γ Vibr. par. 1 M.L.	Li	1·5297	1·5294	1·5375
	C	1·5302	1·5299	1·5380
	Na	1·5335	1·5331	1·5412
	Tl	1·5369	1·5365	1·5446
	F	1·5410	1·5405	1·5488
	G	1·5471	1·5466	1·5549

Fig. 2.
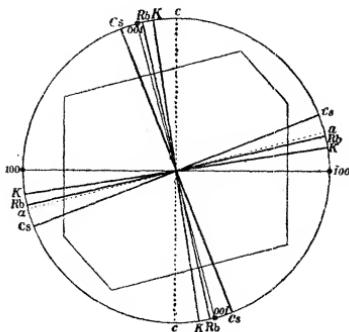
The best mode of comparing the refraction of the three salts is probably to take the mean of all three indices, for an intermediate wave-length, of each salt, and to set these mean indices side by side. Such values for sodium light are given below.

Mean refractive index of KZn selenate for Na light...   1·5212

                                                              Diff. 26

   ,,   ,,   RbZn   ,,   ,,   ... 1·5238

                                                ,, 129

   ,,   ,,   CsZn   ,,   ,,   ... 1·5367

The mean refractive indices of the K, Rb, and Cs zinc sulphates are 1·4859, 1·4897, and 1·5054. The differences, 38 and 157, are thus reduced when sulphur is replaced by selenium.

Comparison of Double Refraction, $Na\gamma_{-a}$.

For KZn selenate ....0·0214

                                     Diff. 45

,, RbZn   ,, ...0·0169

                                       ,, 83

,, CsZn   ,, ...0·0086

The difference for the first replacement, 45, is thus nearly double that of the mean refraction, 26. This explains why, in spite of the general progression in refraction, the γ indices of RbZn selenate are slightly less than those of the KZn salt.

The relations of the refractive powers of the three salts are concisely expressed by the axial ratios of the optical ellipsoid, which are compared beneath, and even more clearly by the continuous curves in fig. 3, which express them graphically.

Comparison of the Optical Ellipsoids.

Optical Indicatrix.

		α	β	γ	Double refraction.
KZn selenate		0·9960 :	1 :	1·0101	141
RbZn	,, ...	0·9961 :	1 :	1·0072	111
CsZn	,, ...	0·9977 :	1 :	1·0033	56

Optical Velocity Ellipsoid.

		$\mathfrak{a}$	$\mathfrak{b}$	$\mathfrak{c}$	
KZn selenate		1·0040 :	1 :	0·9900	140
RbZn	,, ...	1·0039 :	1 :	0·9929	110
CsZn	,, ...	1·0024 :	1 :	0·9968	56

Comparison of the Optical Indicatrices when $\beta_{\mathrm{KZn}} = 1$.

		α		β		γ	
KZn selenate		0·9960	:	1	:	1·0101	
			28		27		2
RbZn	,, ...	0·9988	:	1·0027	:	1·0099	
			108		92		53
CsZn	,, ...	1·0096	:	1·0119	:	1·0152	

The last series of ratios shows the total change of the ellipsoid on passing from one salt to another, and the numbers are obtained by considering the initial length of the β axis, that is, its length in the potassium salt, as unity. They are graphically expressed by the dotted curves in fig. 3.

FIG. 3.
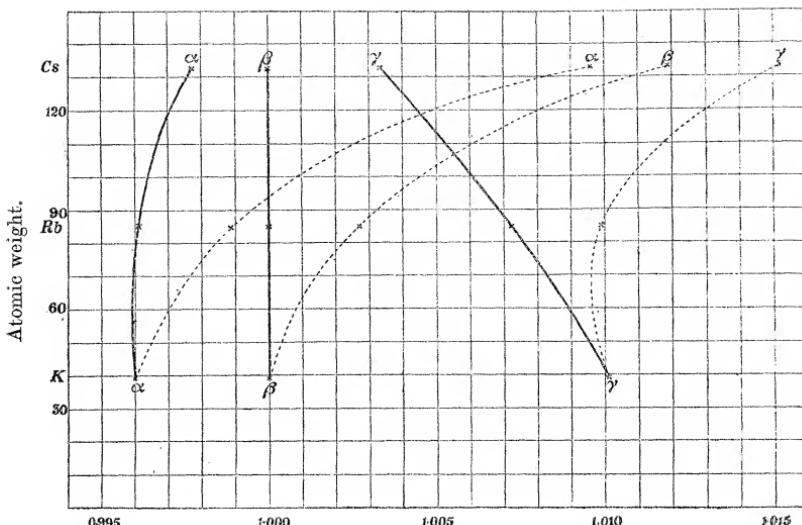
Axial ratios of optical indicatrix.

Besides the main conclusion regarding these axial ratios, given in the Abstract, it will be observed that a notably less change occurs in the length of the γ axis of the indicatrix than along the other two axes, when the total change is considered; this is illustrated by the less sweep of the corresponding curve of the dotted series shown in fig. 3.   When the relative change only is considered the reverse is observed, the change along the γ axis being the maximum, and its curve of the continuous series in fig. 3 taking the greater sweep.   The relative relationships of the three axes to one another, in the case of each salt, govern the magnitude of the optic axial angle of each salt, and the fact that the positions for the rubidium salt are intermediate, points to an intermediate optic axial angle for that salt, an expectation which the next table shows is fulfilled.

The diminution of the double refraction as the atomic weight of the alkali metal is increased is clearly shown by the ratios, and by the convergence of the curves.

Comparison of True Optic Axial Angles, $2V_a$.

Light.	KZn selenate.		RbZn selenate.		CsZn selenate.	
	°	′	°	′	°	′
Li	66	12	75	16	83	33
C	66	13	75	14	83	30
Na	66	15	75	8	83	6
Tl	66	17	75	2	82	43
F	66	20	74	55	82	14

The symmetry plane is the common plane of the optic axes.   The double refraction is positive for all three salts, and the disposition of the median lines is also identical, subject to the rotation of the whole optical ellipsoid.

Comparison of the Molecular Optical Constants.

Specific Refraction, $\dfrac{n^2 - 1}{(n^2 + 2)d} = \mathfrak{n}$.

	For ray C (Hα).			For ray Hγ near G.		
	α	β	γ	α	β	γ
KZn sel.	0·1170	0·1181	0·1210	0·1199	0·1211	0·1242
	119	119	130	121	122	134
RbZn sel.	0·1051	0·1062	0·1080	0·1078	0·1089	0·1108
	60	66	76	62	67	78
CsZn sel.	0·0991	0·0996	0·1004	0·1016	0·1022	0·1030

Molecular refraction, $\dfrac{n^2-1}{n^2+2} \cdot \dfrac{M}{d} = \mathfrak{m}$.

	For ray C (Hα).			For ray Hγ near G.		
	α	β	γ	α	β	γ
KZn sel.	62·76	63·37	64·93	64·33	64·98	66·65
		3·37	3·40	2·99	3·47	3·49	3·05
RbZn sel.	66·13	66·77	67·92	67·80	68·47	69·70
		5·60	5·37	4·77	5·78	5·51	4·88
CsZn sel.	71·73	72·14	72·69	73·58	73·98	74·58

Specific Dispersion, $\mathfrak{n}_G - \mathfrak{n}_C$.

	α	β	γ
KZn sel.	0·0029	0·0030	0·0032
RbZn sel.	0·0027	0·0027	0·0028
CsZn sel.	0·0025	0·0026	0·0026

Molecular Dispersion, $\mathfrak{m}_G - \mathfrak{m}_C$.

	α	β	γ
KZn sel.	1·57	1·61	1·72
RbZn sel.	1·67	1·70	1·78
CsZn sel.	1·85	1·84	1·89

Molecular Refraction (Gladstone), $\dfrac{n-1}{d}$ M.

	α	β	γ
KZn sel.	107·00	108·24	111·41
		5·90	5·96	5·12
RbZn sel.	112·90	114·20	116·53
		10·16	9·69	8·50
CsZn sel.	123·06	123·89	125·03

The rules stated in the Abstract regarding specific and molecular refraction are independent of the wave-length, and whether they are calculated by the formulæ of Lorenz or Gladstone and Dale. They are also independent of temperature, for it has been shown with regard to each salt that the refraction is diminished by rise of temperature, and the density, the other factor in the calculation, is naturally affected in the same direction by increase of temperature.

The replacement of sulphur by selenium in these zinc double salts is accompanied by an increase of molecular refraction of 7·0—7·4 Lorenz units or 13·0—13·9 Gladstone units for the ray C, according to the direction compared. The increase due to each atom is thus 3·5—3·7 or 6·5—6·9 units. The values derived from a comparison of the simple sulphates and selenates were 3·4—3·8 or 6·2—7·2. The mean values derived from the two series are thus identical.

In the next communication the magnesium group of salts will be described.